Key benefits and principles of Isothermal and Adiabatic calorimetry

Joseph Willmot – 16/12/2020

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Presenters

Joseph Willmot – Application Leader

Spent 3 years as a Project Manager, which allowed him insight into the functionality of the various equipment H.E.L produces. He is now utilising this knowledge as Application Leader, where he is now looking at customers usage of the equipment, and helps them find the best solution for their application

Main Outcomes

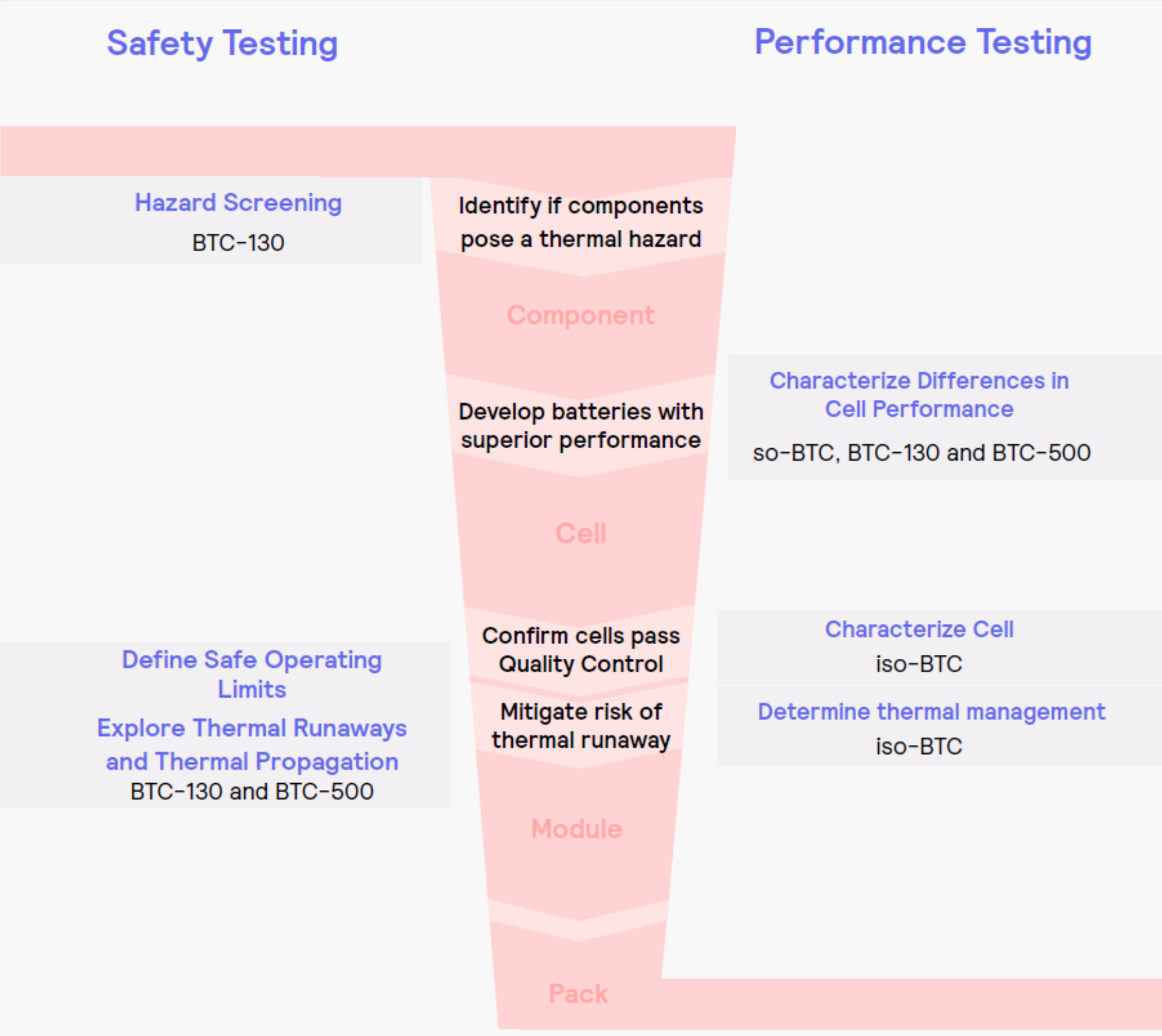
Isothermal calorimetry with batteries

- What are the basic principles of isothermal calorimetry?
- What information do we gain from isothermal calorimetry, and why do I care?
- What does this information mean and what can I do with it?

Adiabatic calorimetry with batteries

- What are the basic principles of adiabatic calorimetry with batteries?
- Why is it appropriate to gather this information for batteries?
- Why do I care about this information?

Battery Development Testing



Performance Testing

Isothermal Calorimetry

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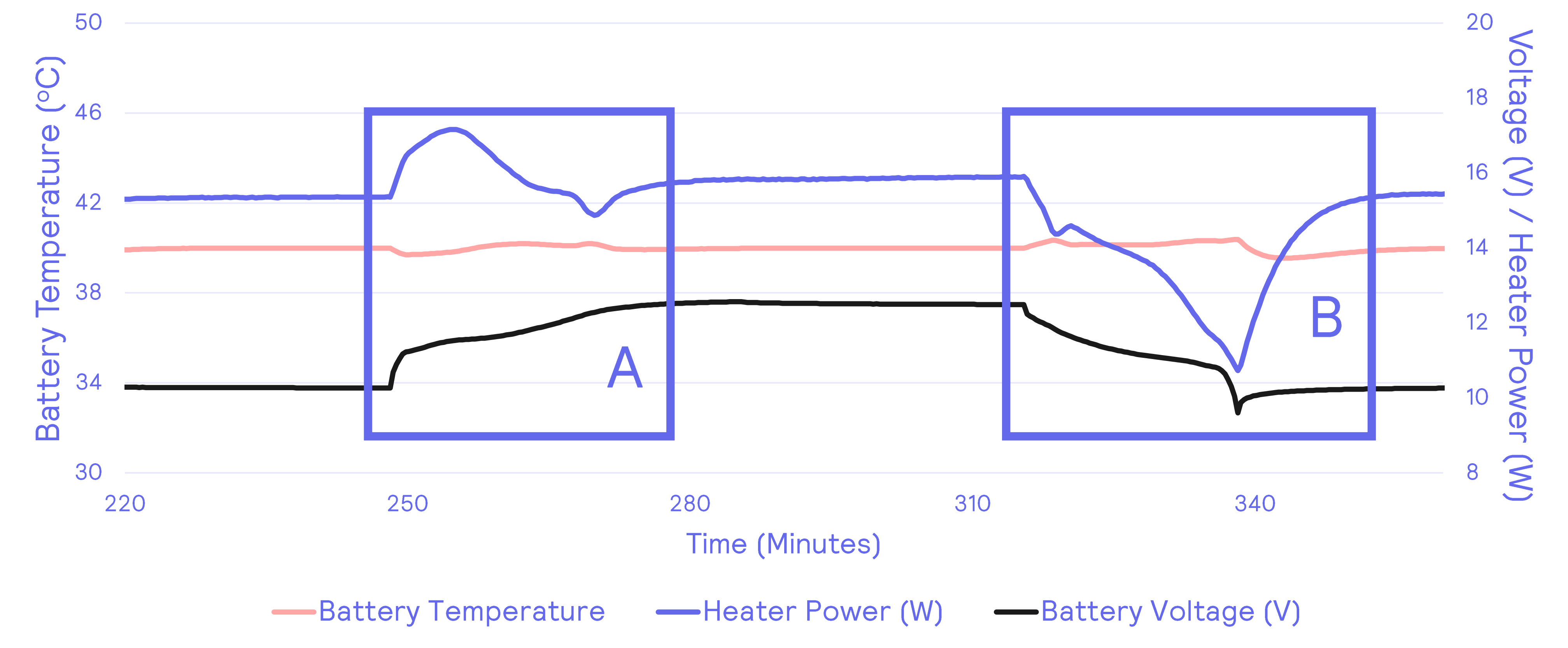
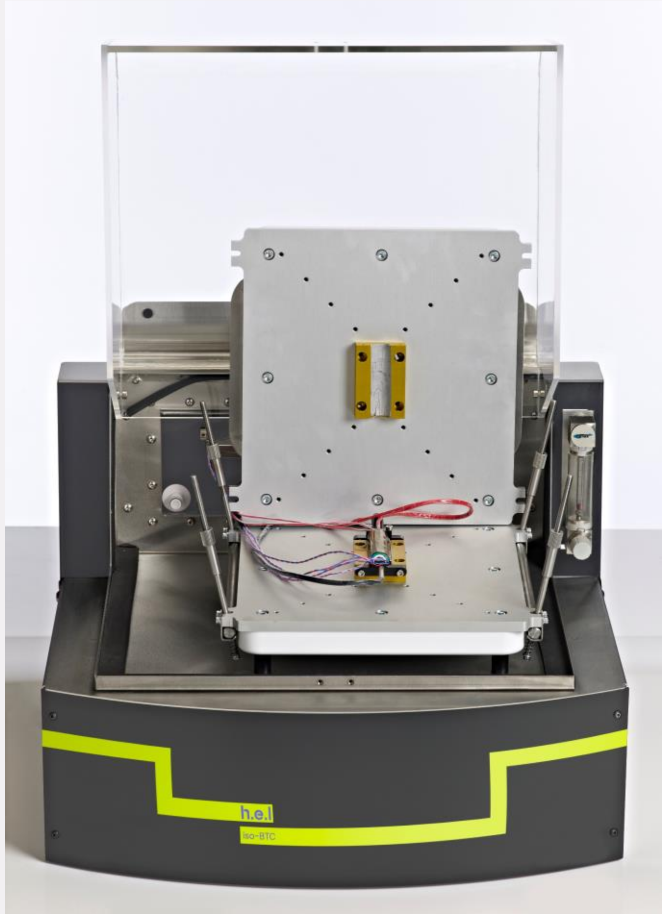
Isothermal Performance Testing



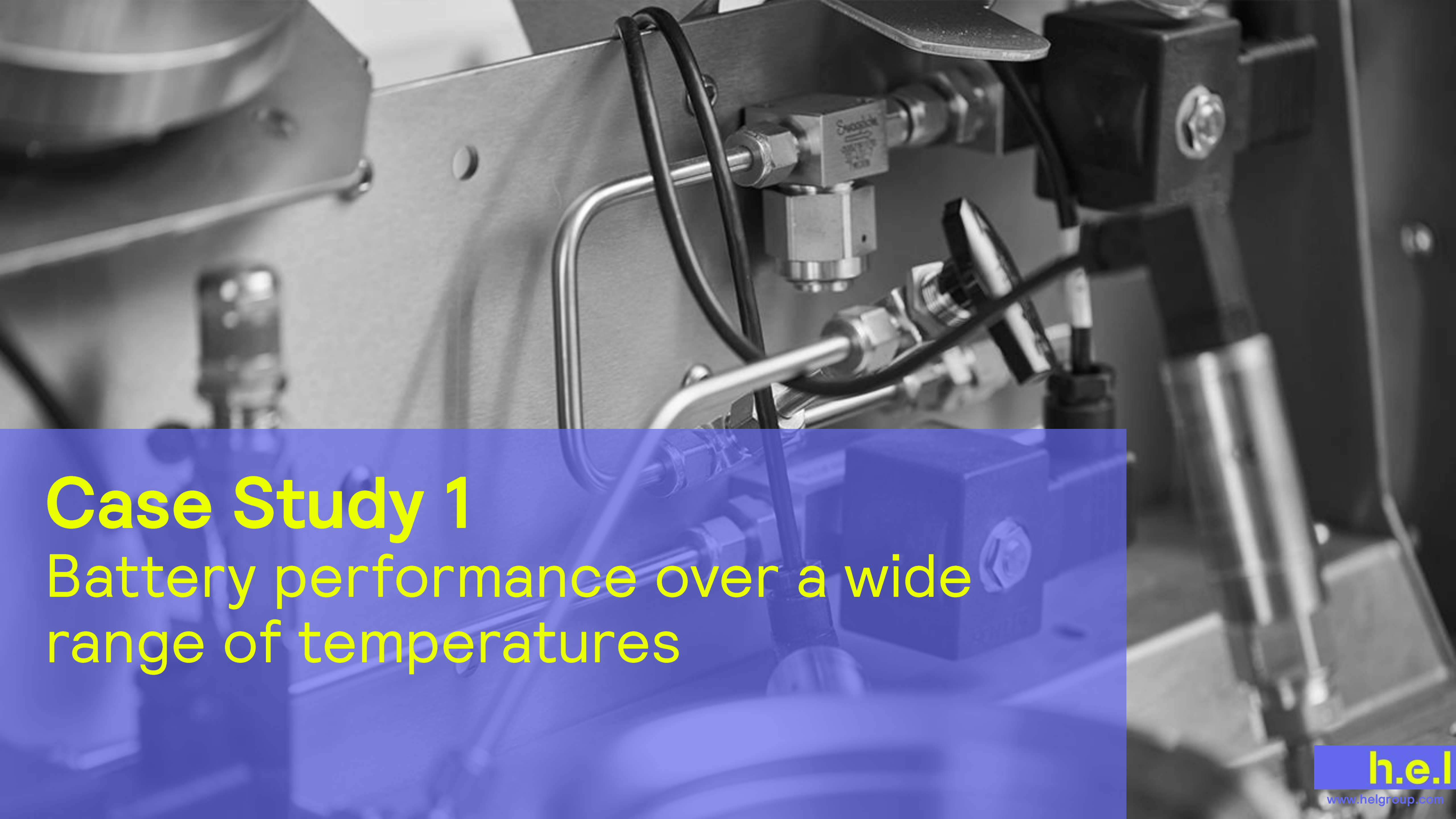
- Non-abusive, non-destructive testing.
- A highly sensitive investigative technique

Testing equipment



- Utilizes H.E.L's iso-BTC calorimeter, which utilizes power compensation for temperature control.

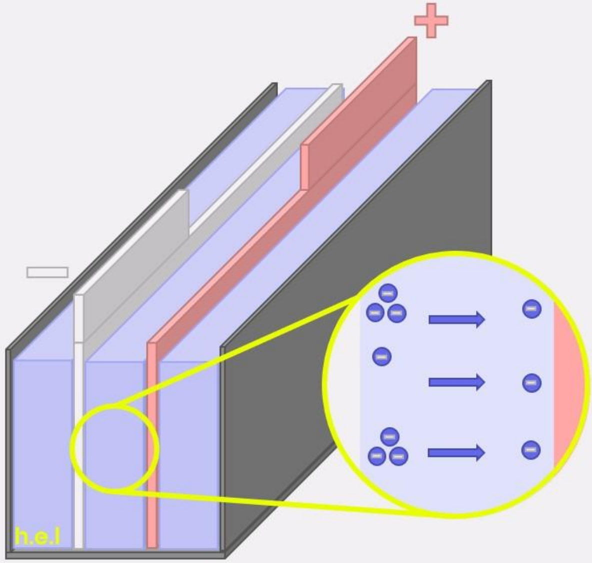
- A charge/discharge unit was also utilized (not pictured) and integrated with controlling software, allowing for fully automated testing.



Case Study 1

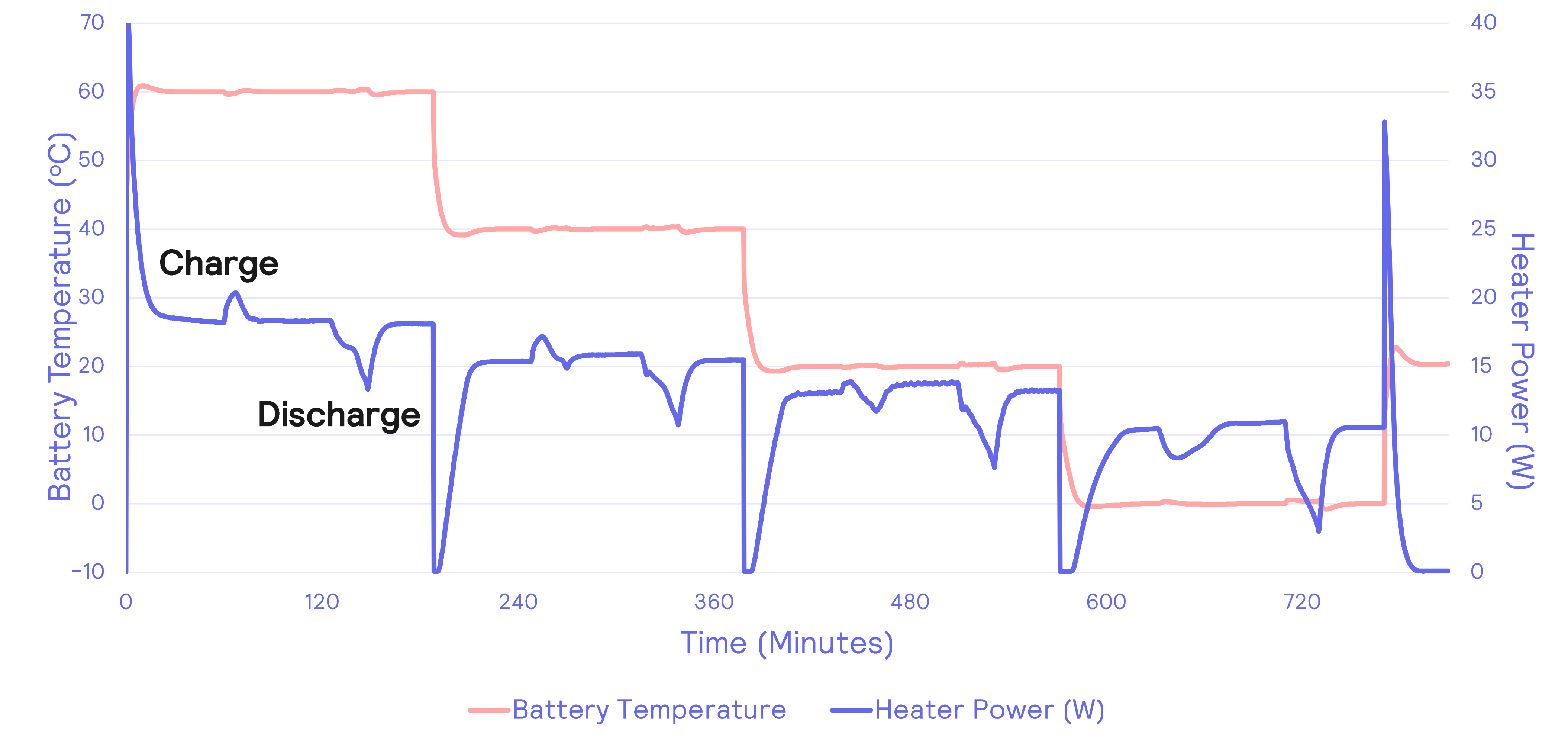
Battery performance over a wide range of temperatures

Case Study 1

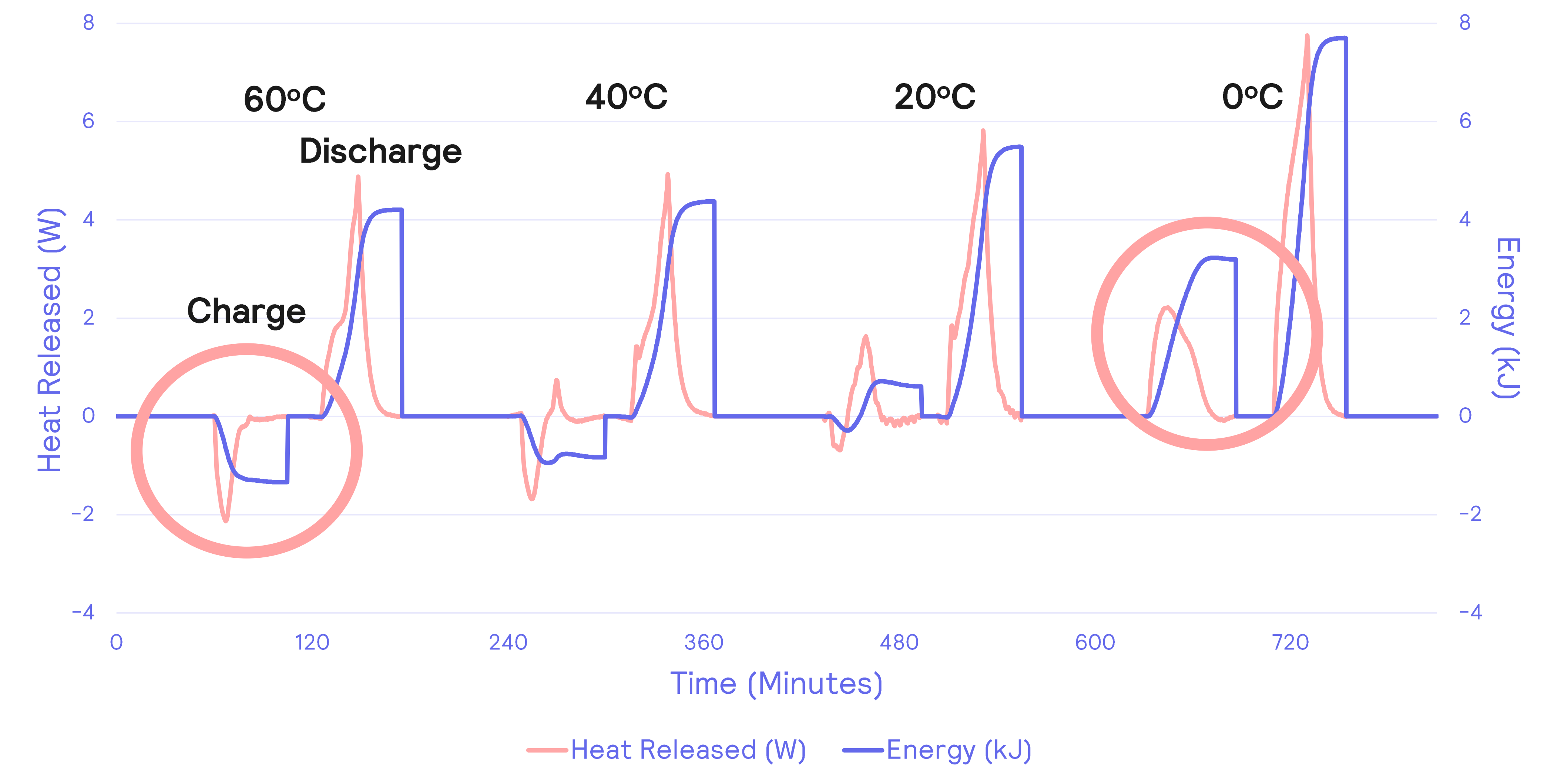


- **Temperature dependence of charge/discharge cycling of Battery A**
- Triple gel cell battery, with 2.2Amp hours capacity.
- Temperatures from 60°C to 0°C were investigated in one test.

Gel Battery – Heat Flow at a Range of Temperatures.



Gel Battery – Heat Flow at a Range of Temperatures.



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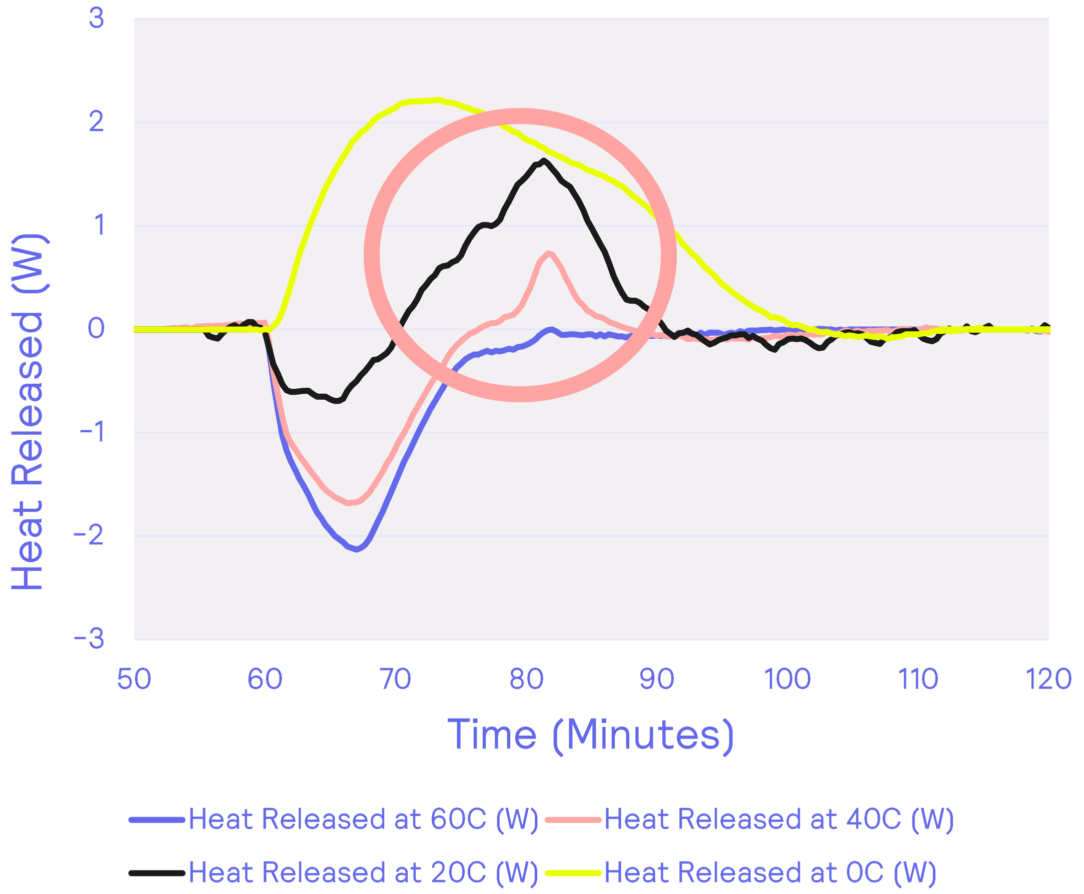
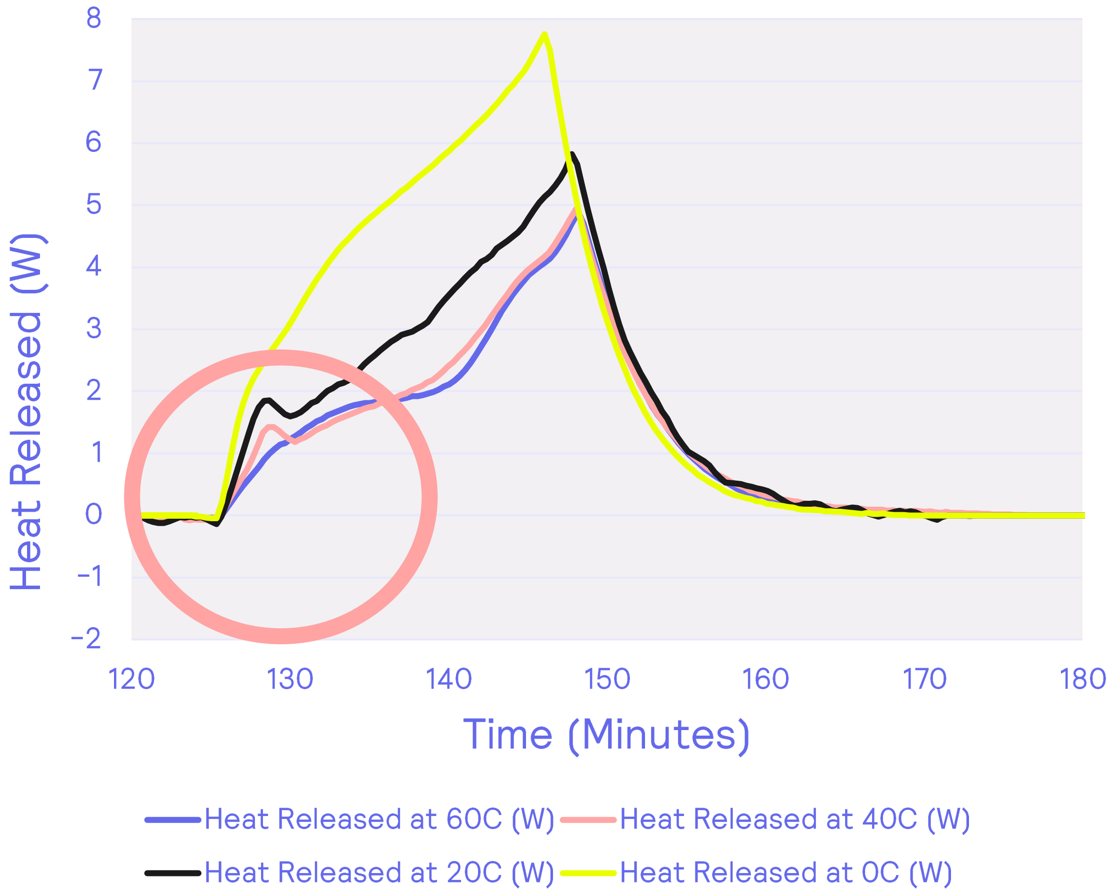
Gel Battery – Heat Flow at a Range of Temperatures.





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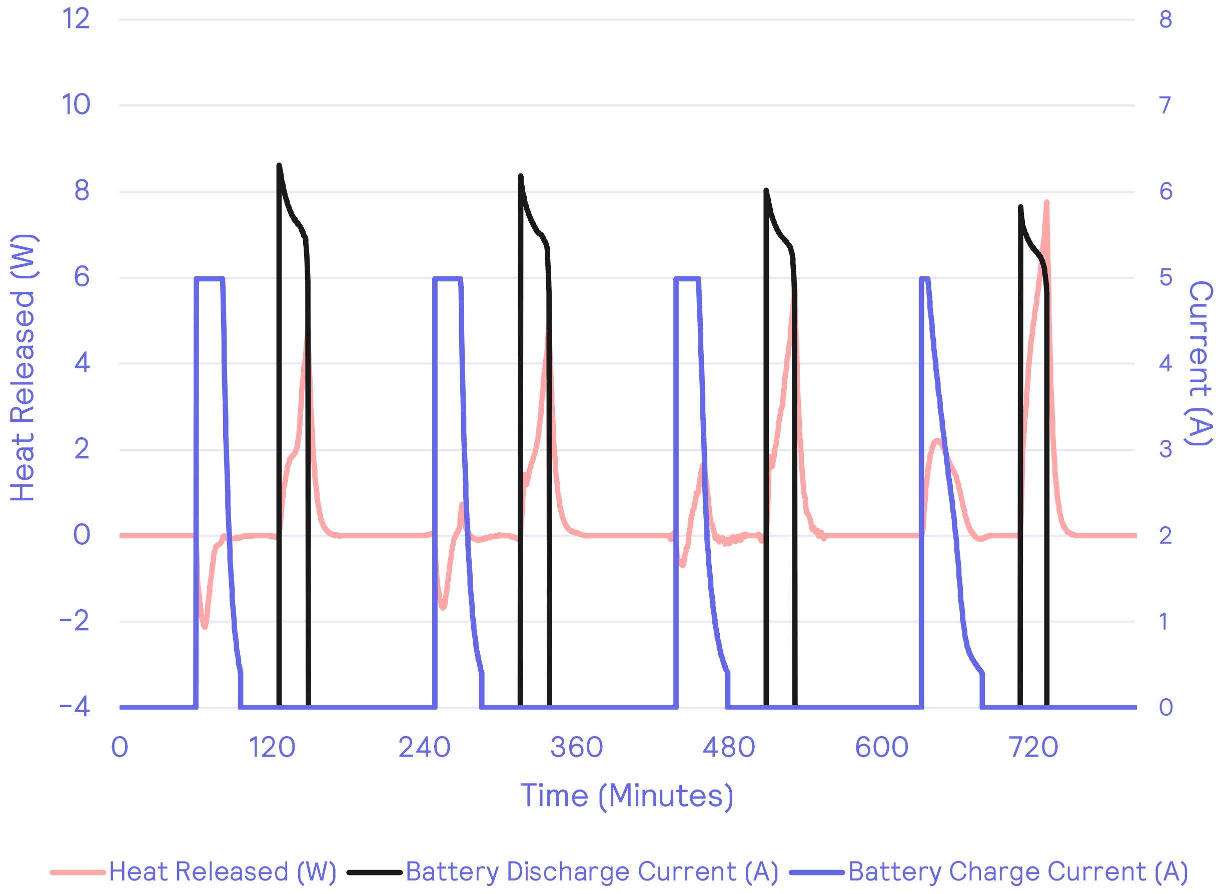
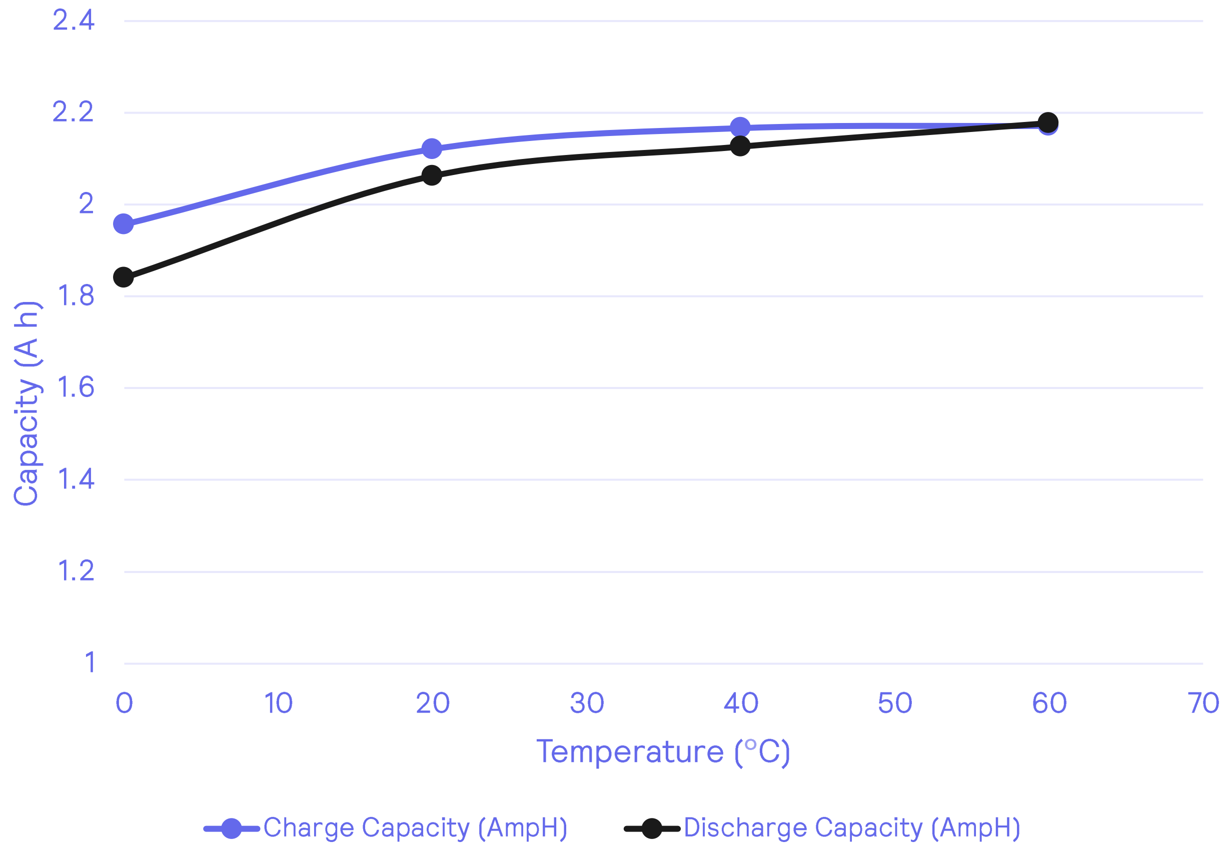
Gel Battery – Capacity at a Range of Temperatures.





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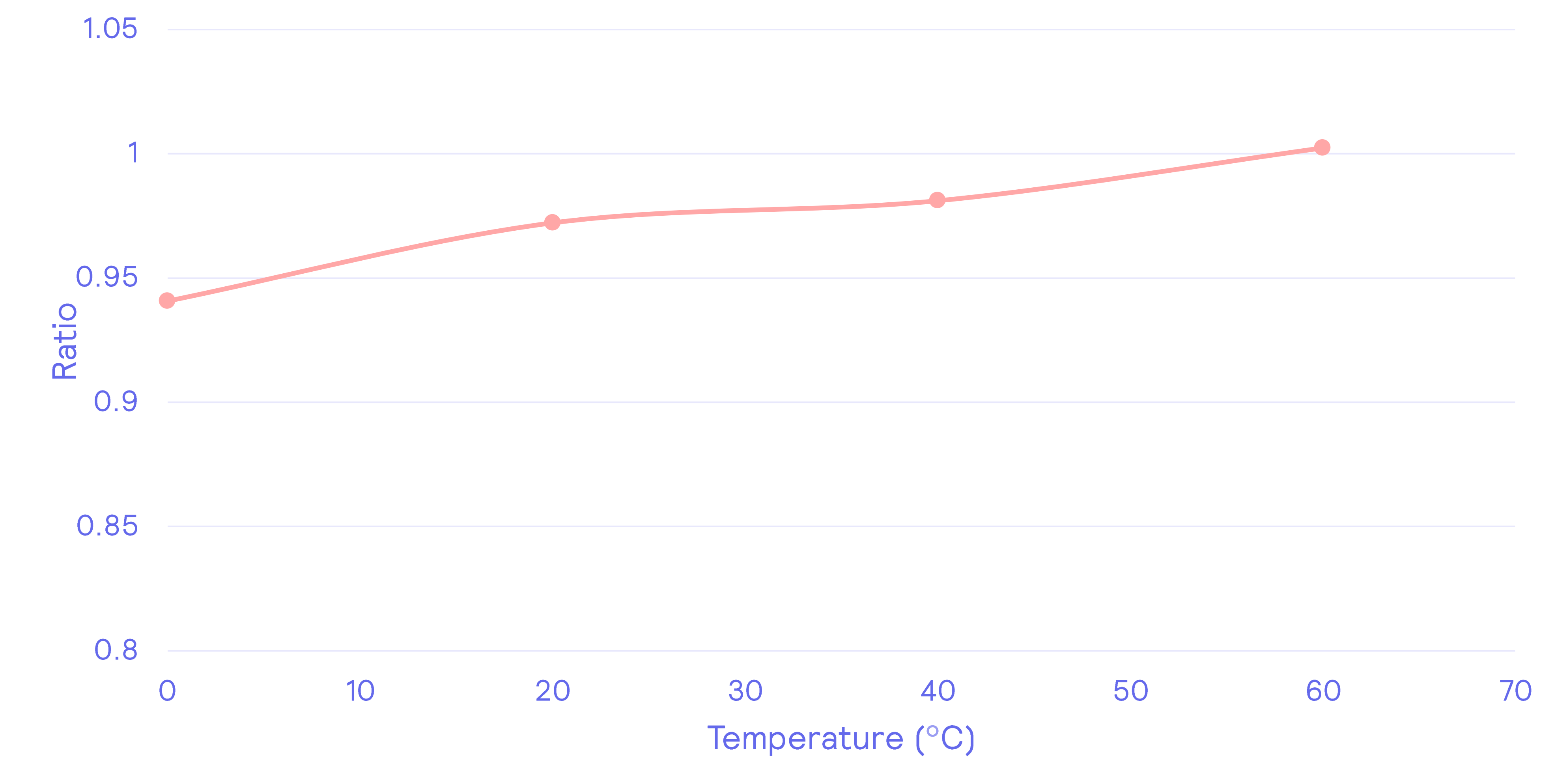
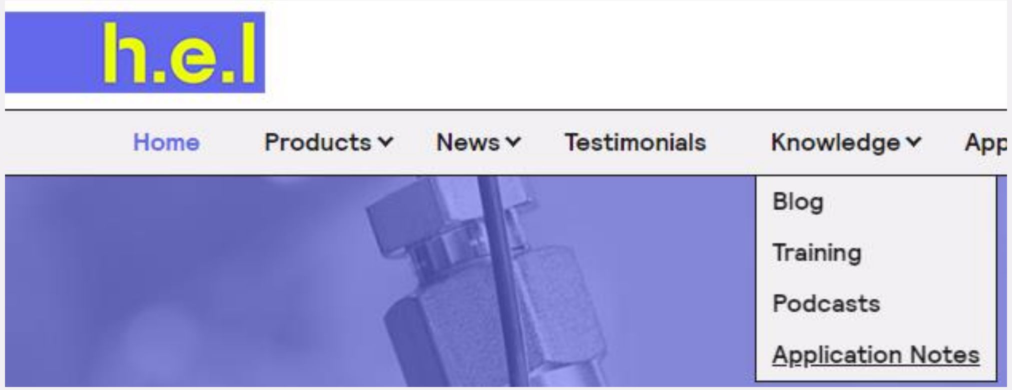
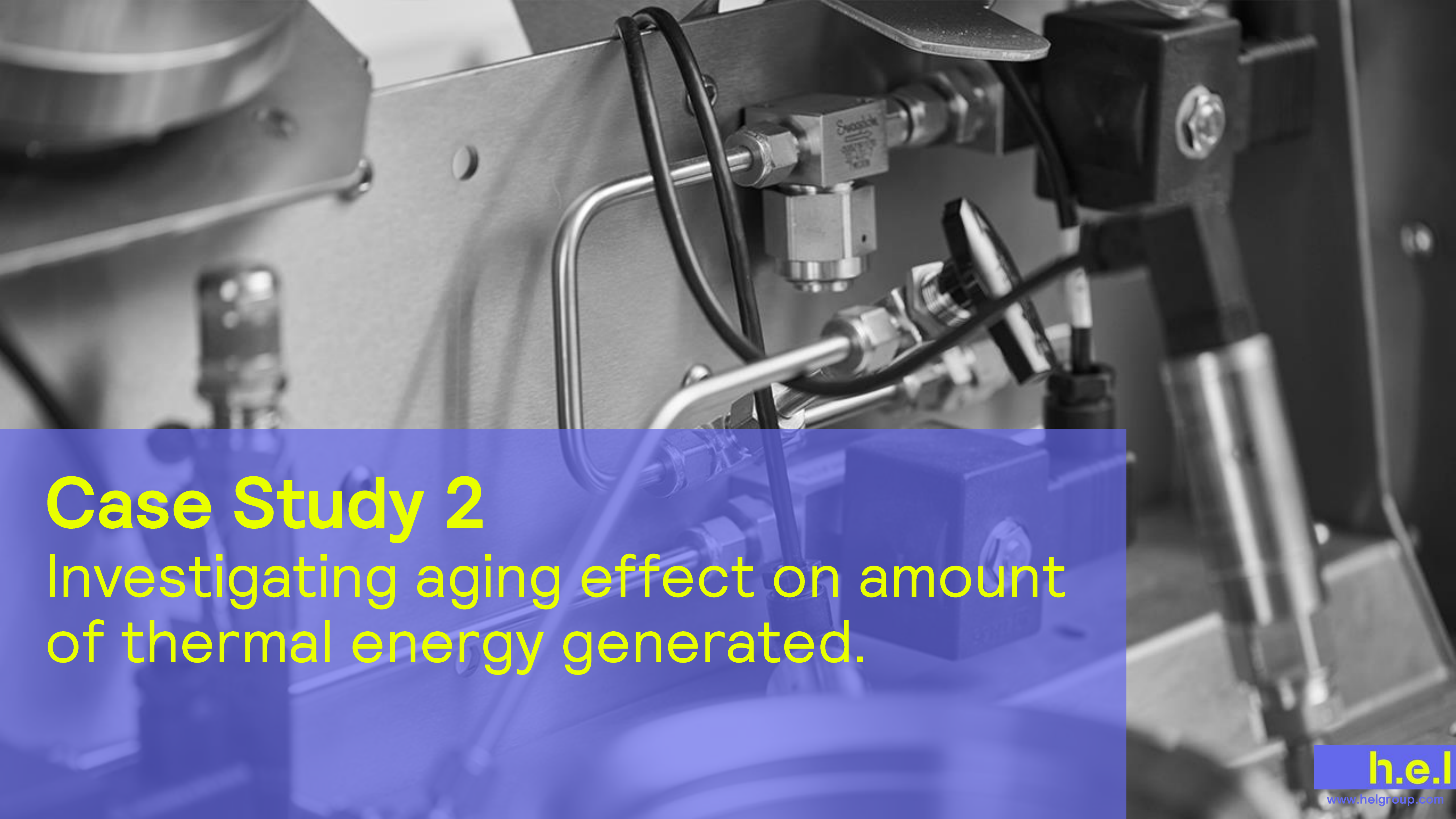
Gel Battery – Efficiency at a Range of Temperatures.



Further reading



https://helgroup.com/knowledge/use-isothermal-calorimeter/



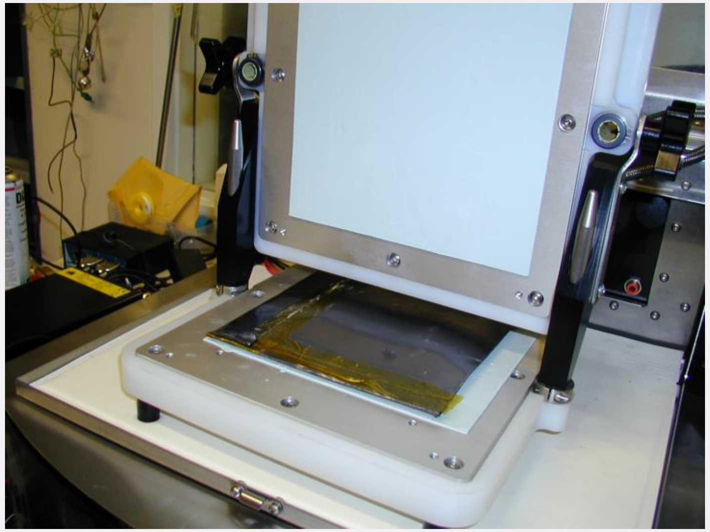
Case Study 2

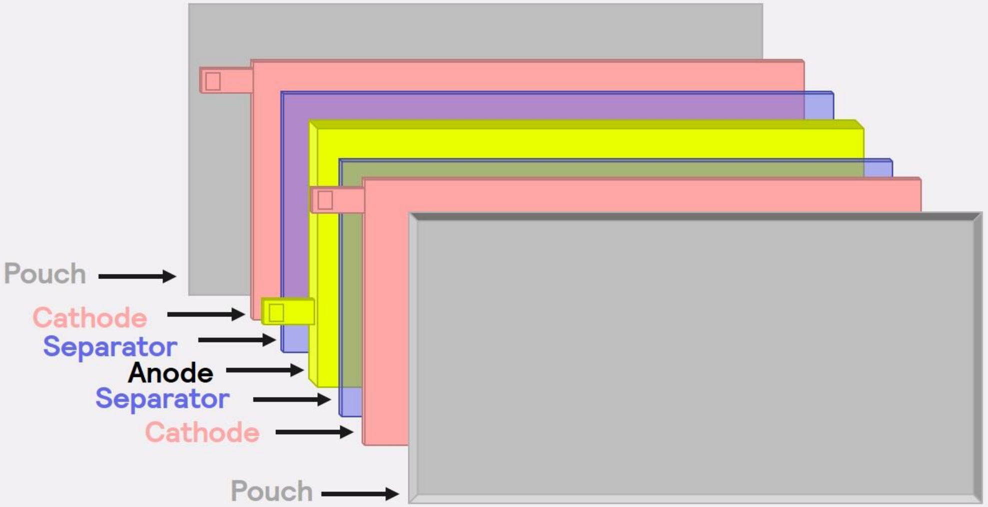
Investigating aging effect on amount of thermal energy generated.

Case Study 2

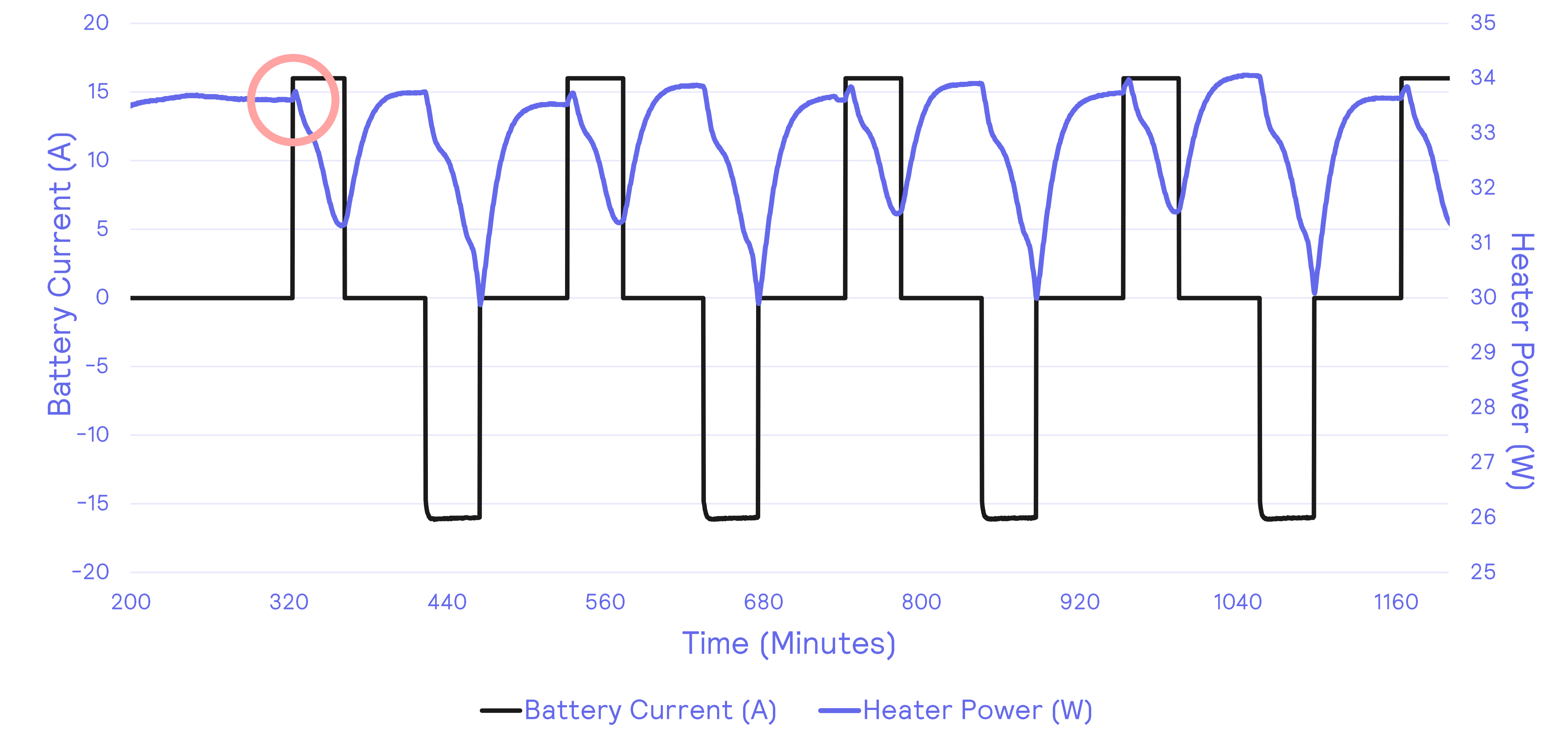
- Investigation into amount of heat released in successive charge/discharge cycles

- 16A pouch cell, cycled between 2.8V and 4.15V





1C Charge – 1C Discharge Cycling



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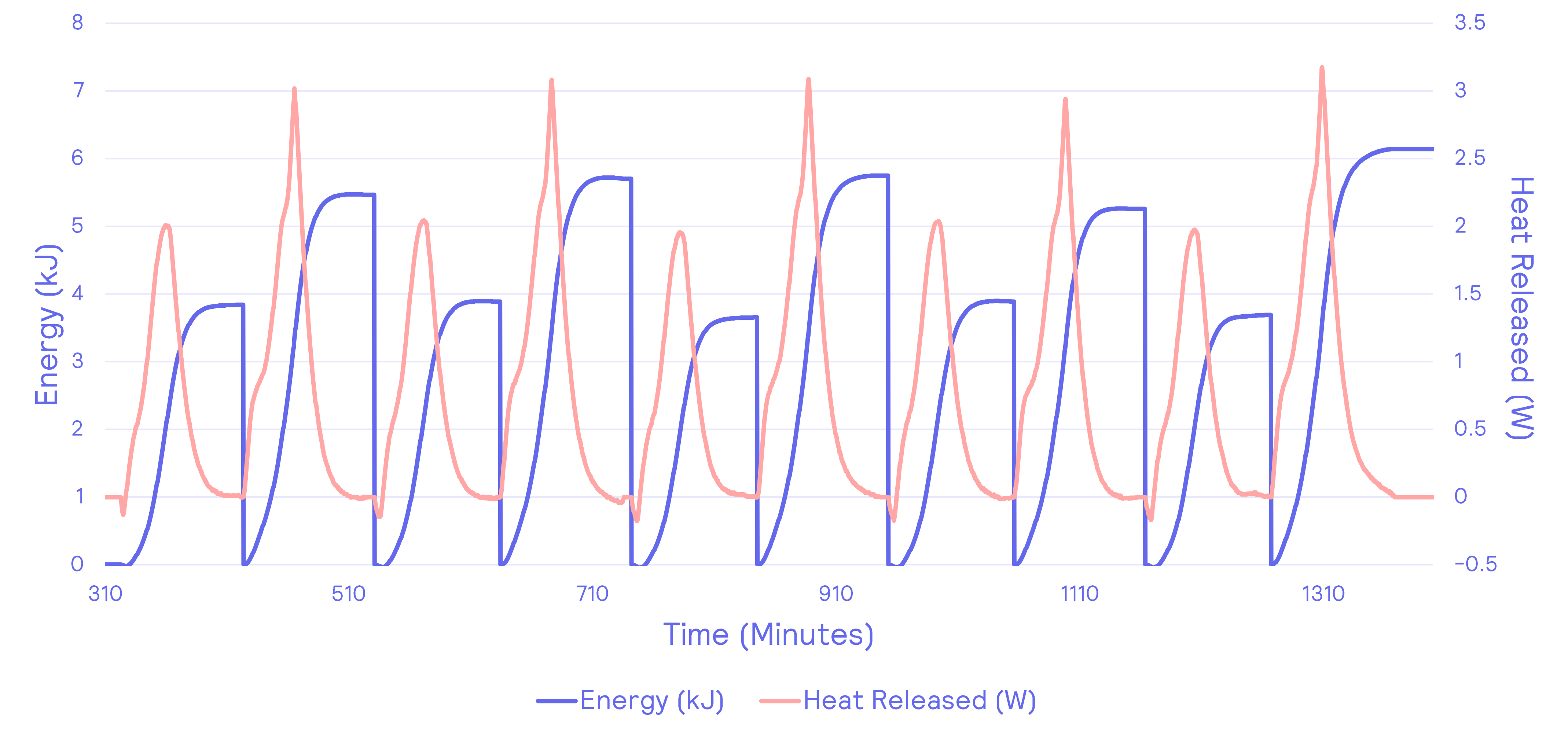
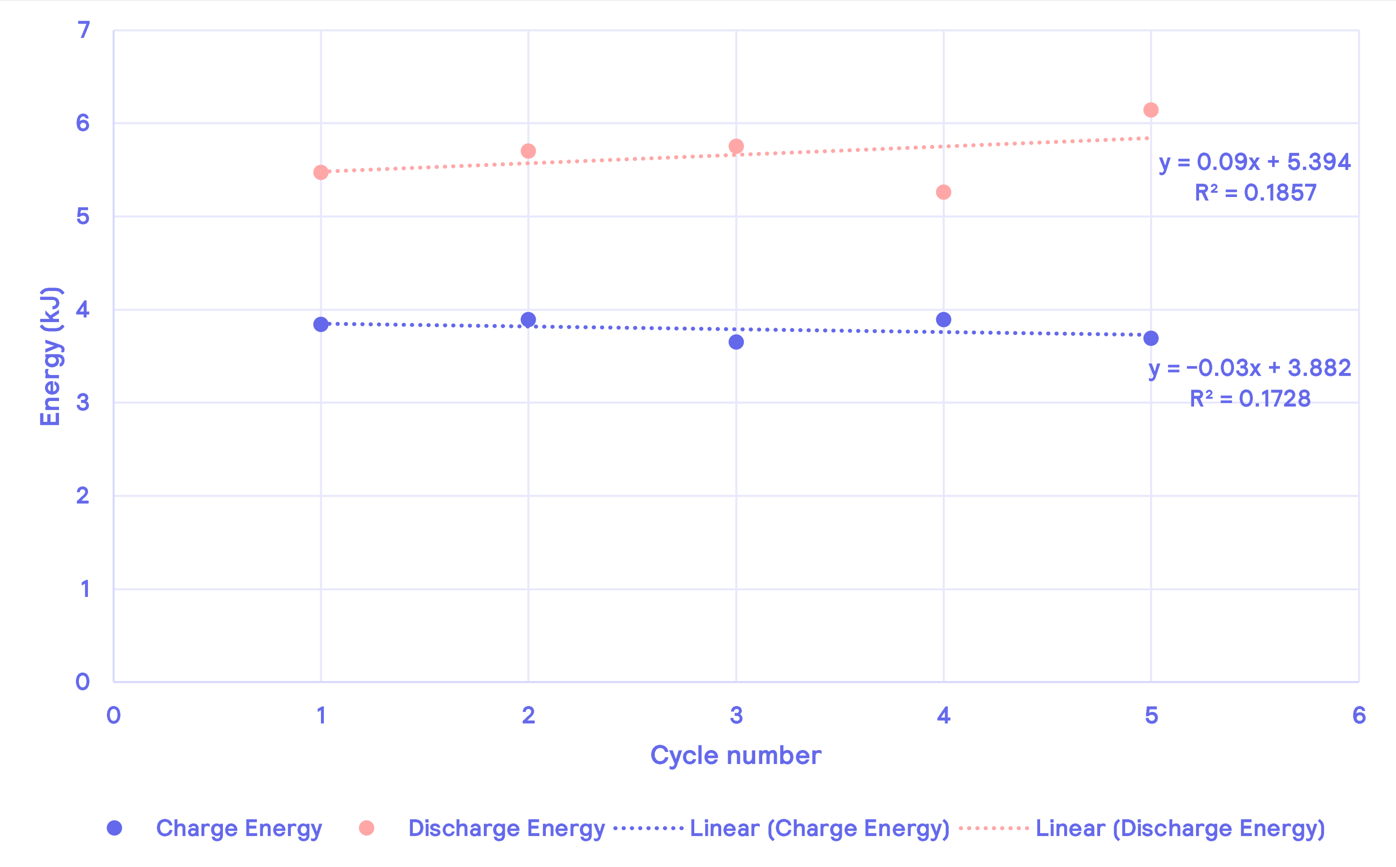
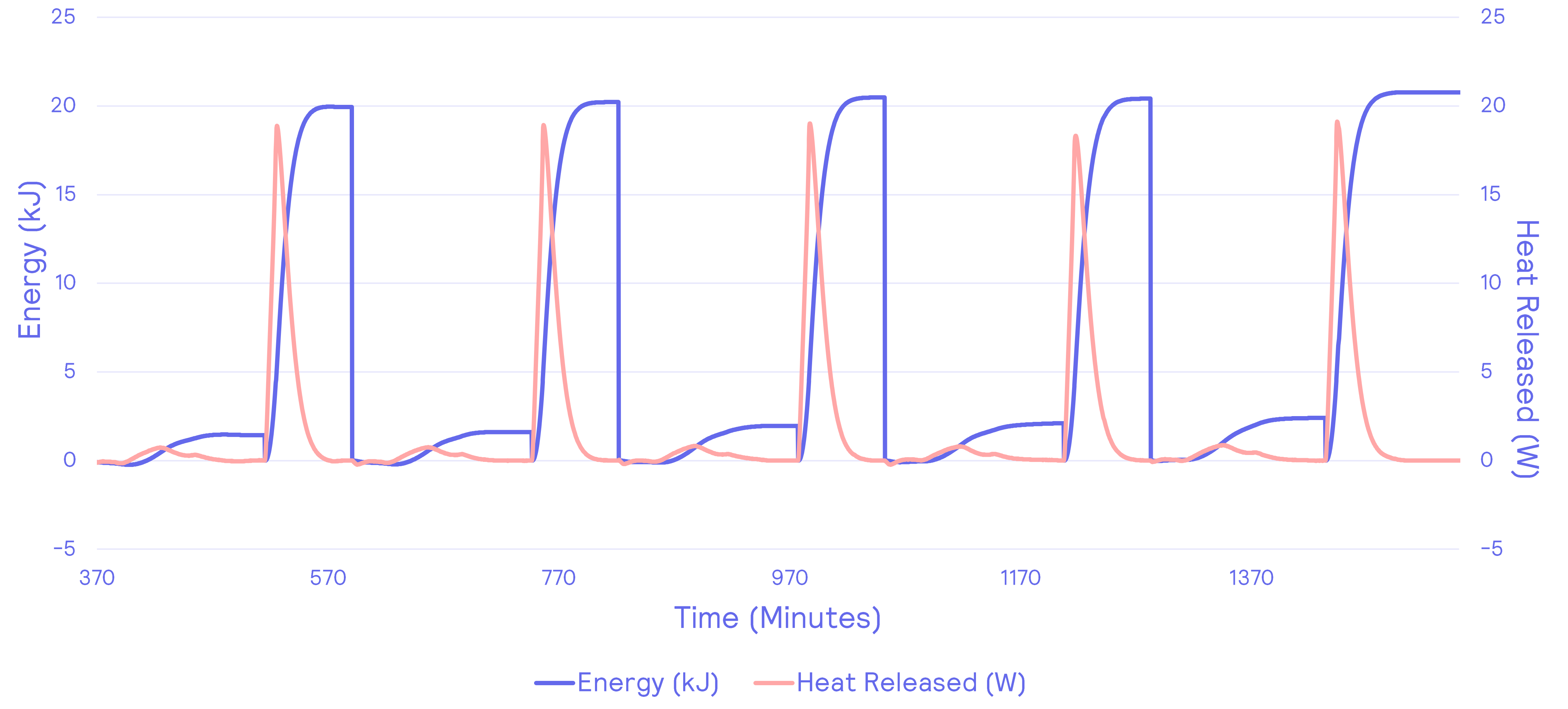


1C Charge – 1C Discharge Cycling

Cycle number	Charge thermal energy (kJ)	Discharge thermal energy (kJ)
1	3.84	5.47
2	3.89	5.70
3	3.65	5.75
4	3.89	5.26
5	3.69	6.14

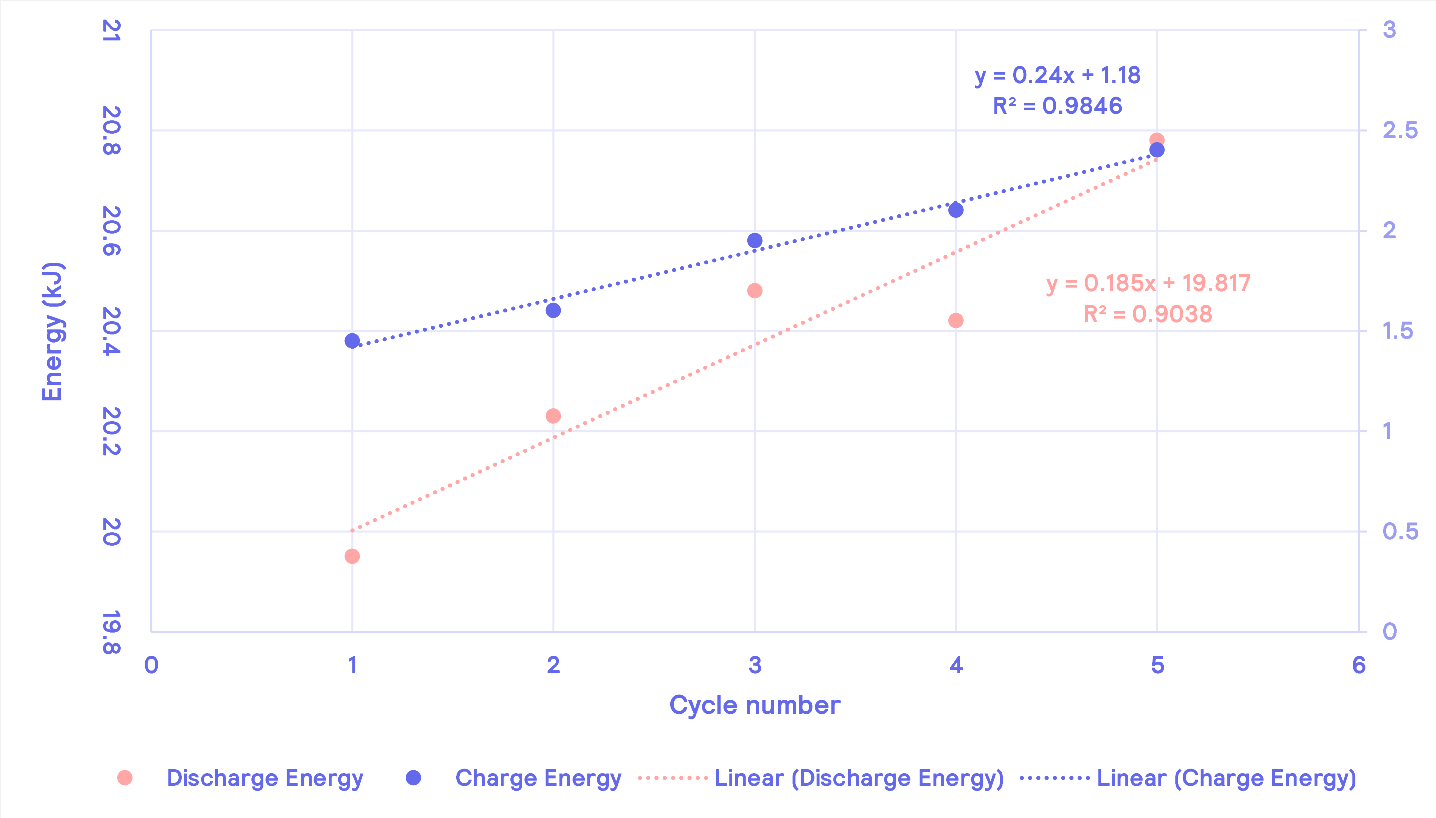


0.5C Charge – 5C Discharge Cycling



0.5C Charge – 5C Discharge Cycling

Cycle number	Charge thermal energy (kJ)	Discharge thermal energy (kJ)
1	1.45	19.95
2	1.6	20.23
3	1.95	20.48
4	2.1	20.42
5	2.4	20.78




Safety Testing
Adiabatic Calorimetry
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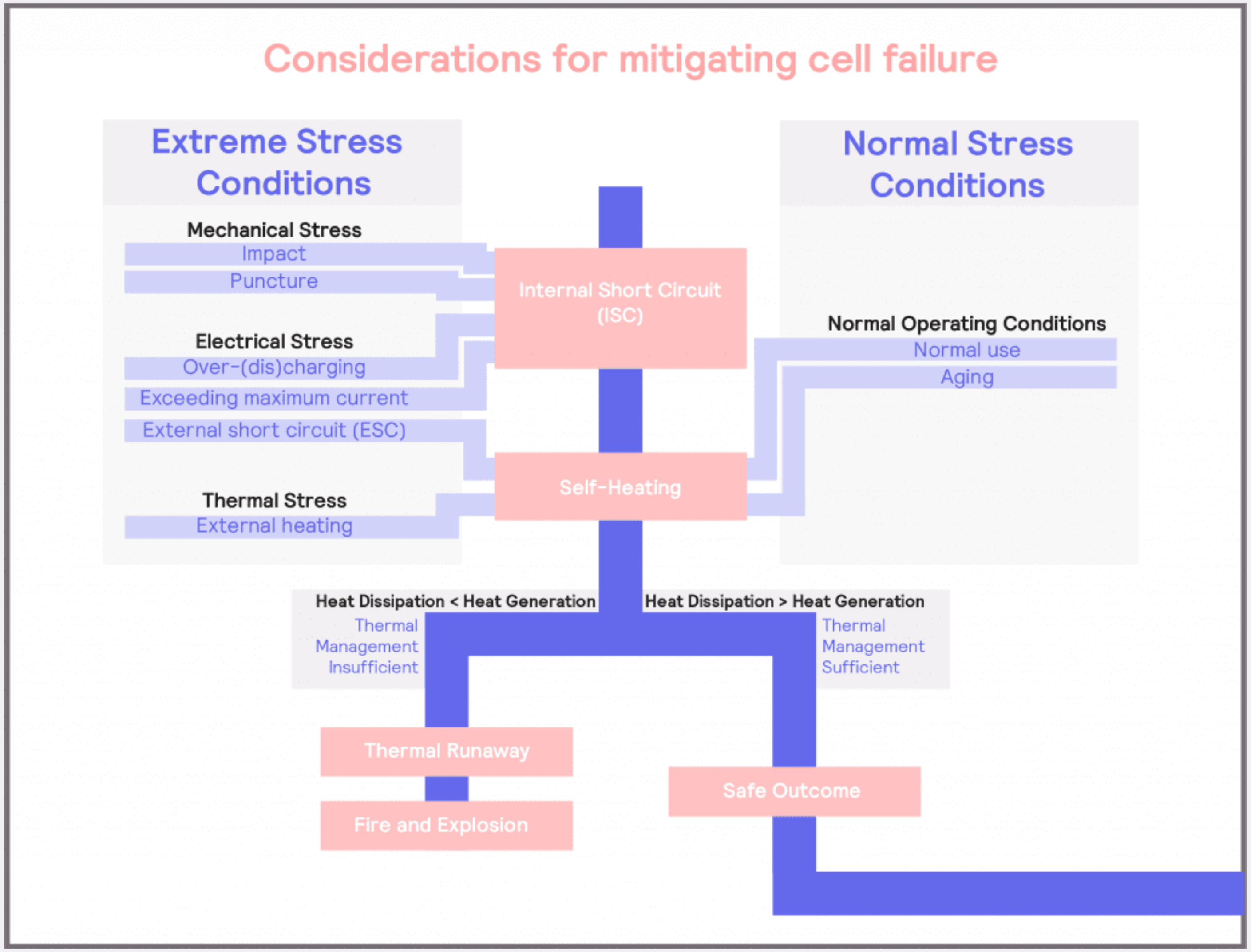
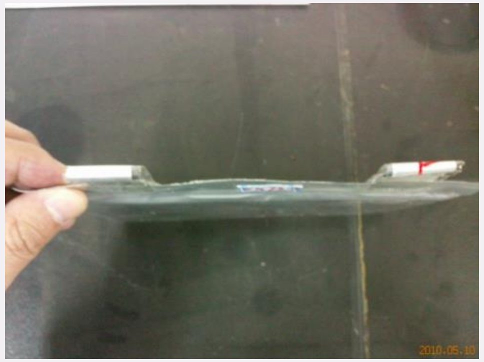
Mitigating cell failure



Testing Procedures

Physical Damage
- Measure the effects of nail penetration



Overcharging and Discharge Rate Risks
- Discharging current, overcharging voltage that causes thermal runaway

Understanding the Effects of Battery Failure
- Amount of gas generated, visual battery damage

Temperature Effects
- At what temperature does battery start to self heat?
  - Define the maximum safe operating temperature
  - Main procedure is a Heat-Wait-Search test

Making Batteries Safer
Better thermal management, information about internal events

Adiabatic testing conditions

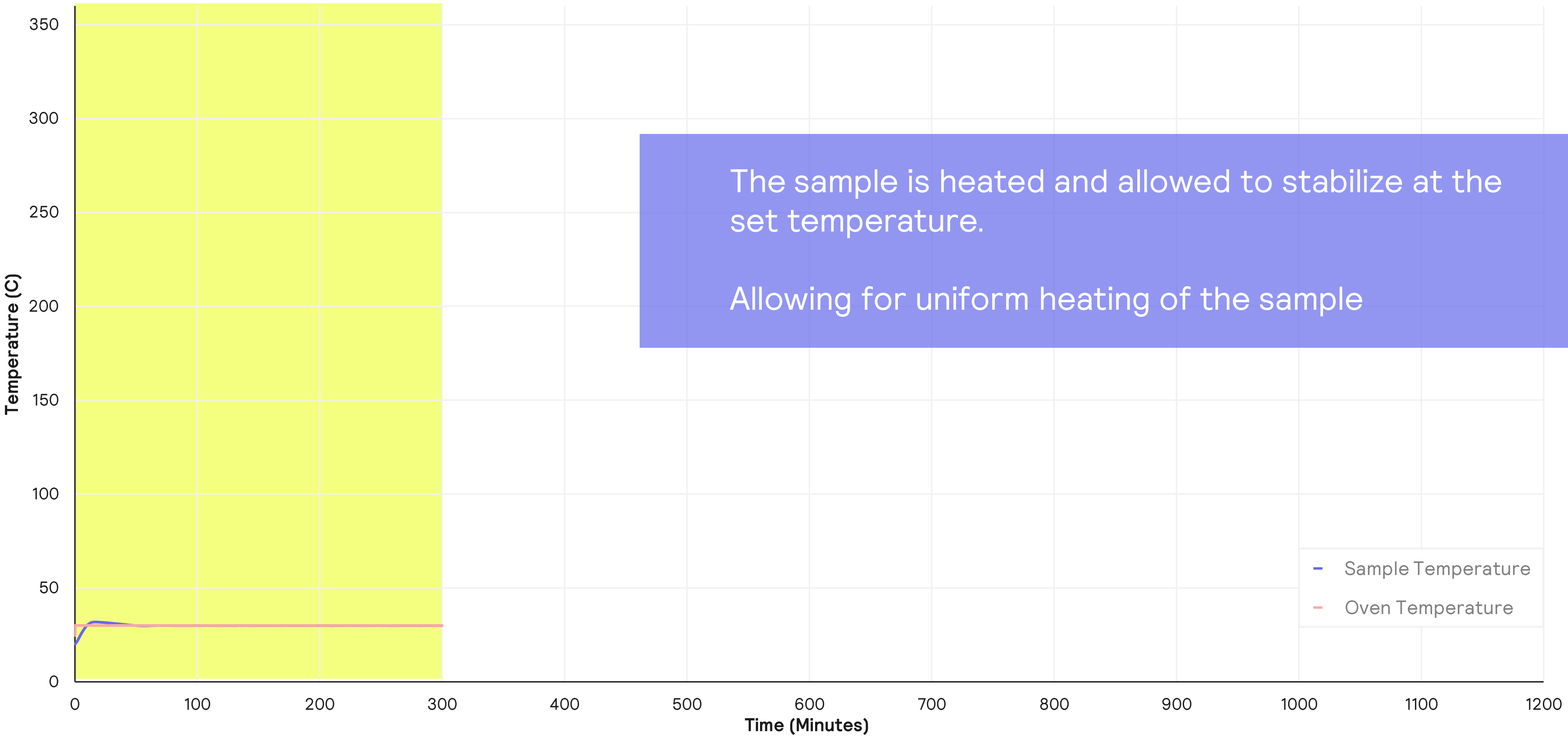
Test batteries in harsh, but realistic conditions

For example

- Cells stacked together,
- Little or no air circulation,
- Environment that gets hot
- High speed on charging

Tesla Model S standard 100kWh battery pack – All rights go to https://www.forbes.com/sites/arielcohen/2020/12/30/teslas-new-lithium-ion-patent-brings-company-closer-to-promised-1-million-mile-battery/?sh=3b8c012633e3

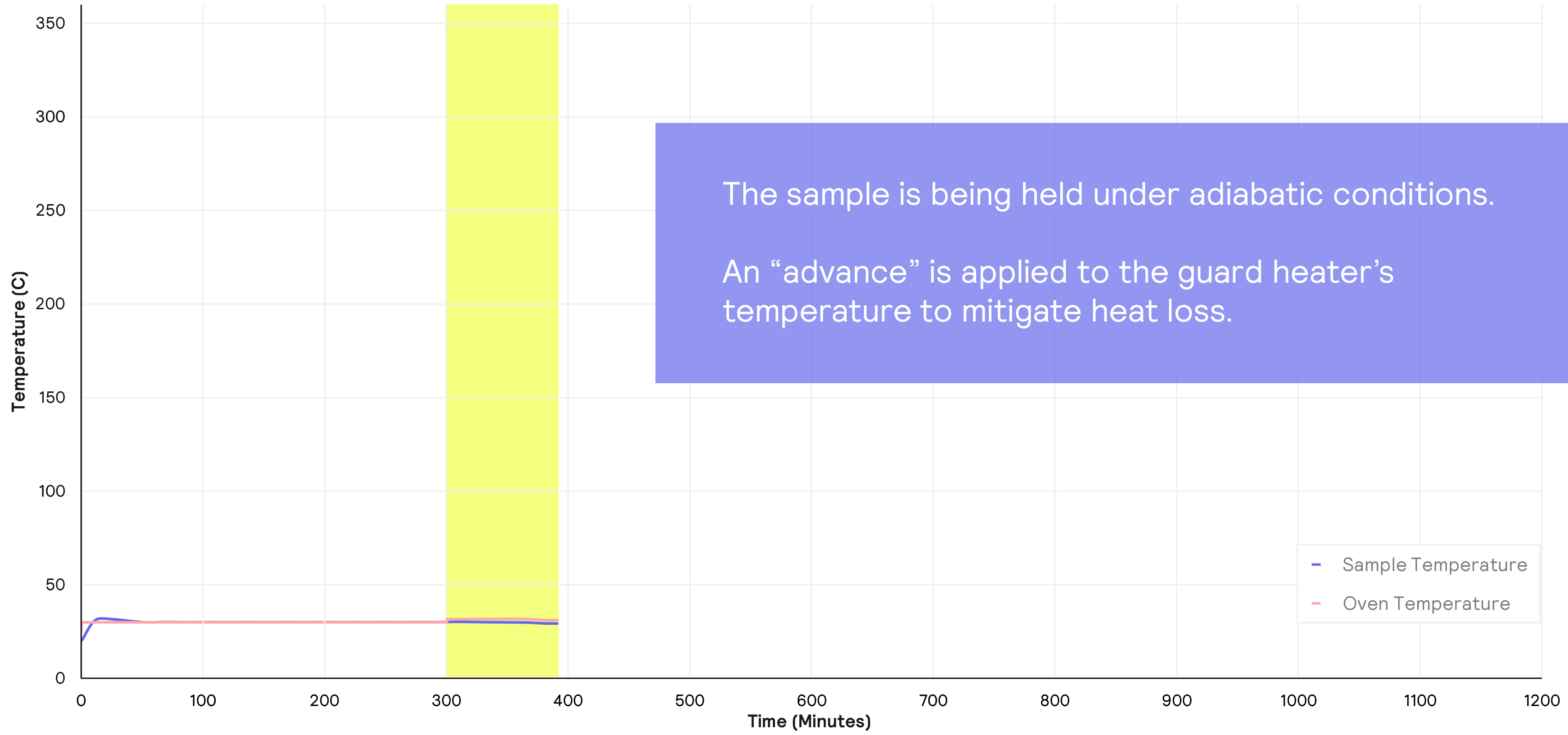
Heat to its Start Temperature



The sample is heated and allowed to stabilize at the set temperature.

Allowing for uniform heating of the sample

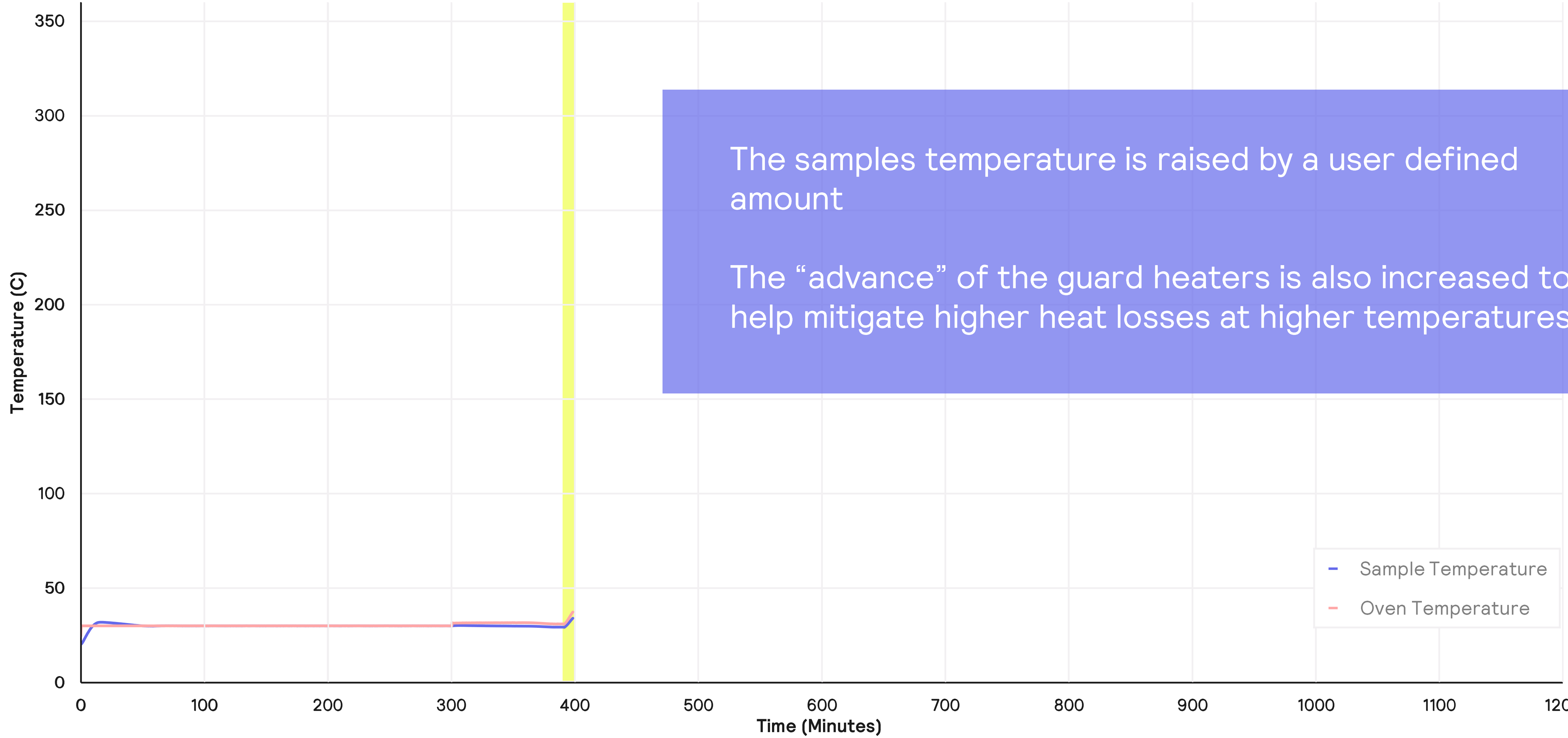
Online Calibration



The sample is being held under adiabatic conditions.

An "advance" is applied to the guard heater's temperature to mitigate heat loss.

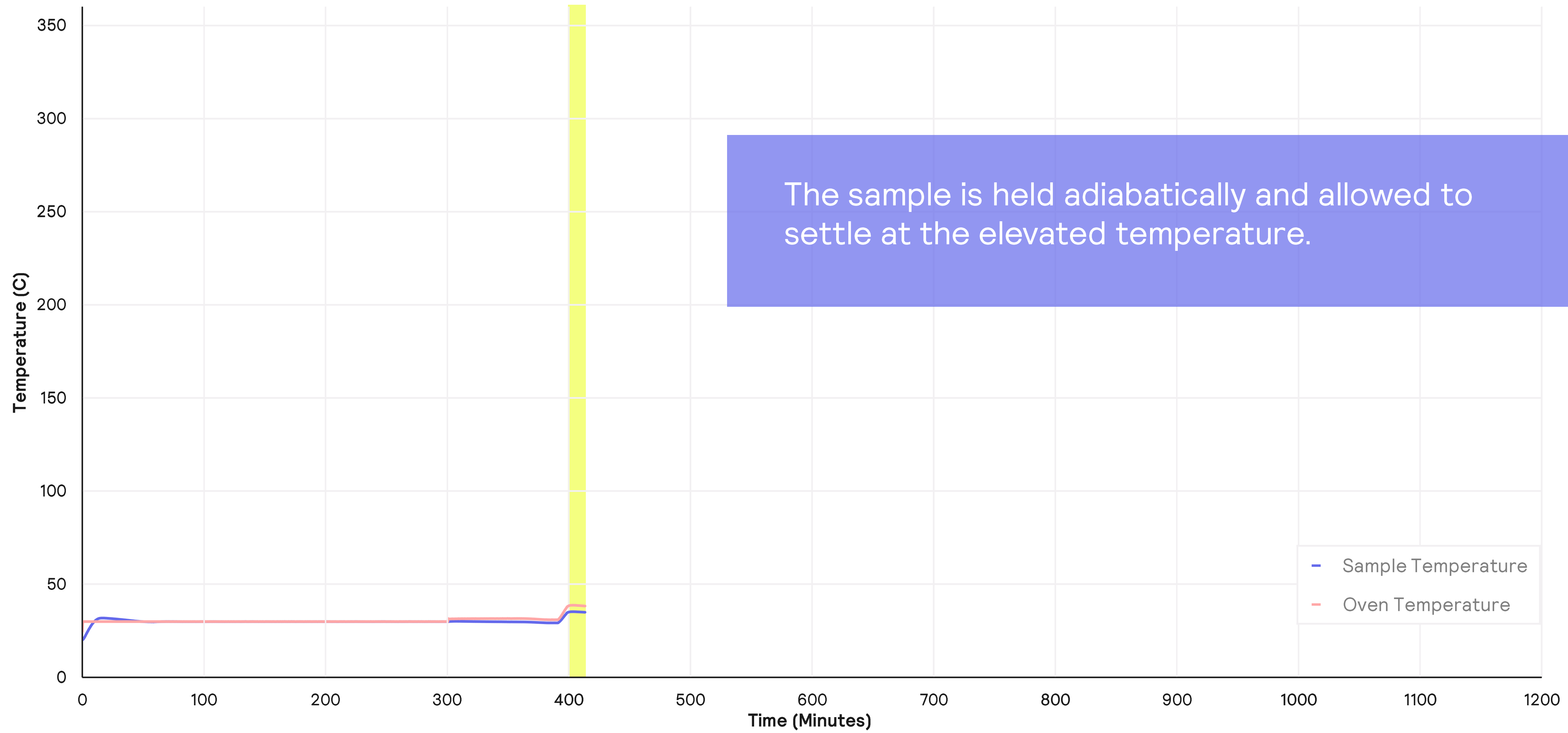
The First "Heat" Step



The samples temperature is raised by a user defined amount

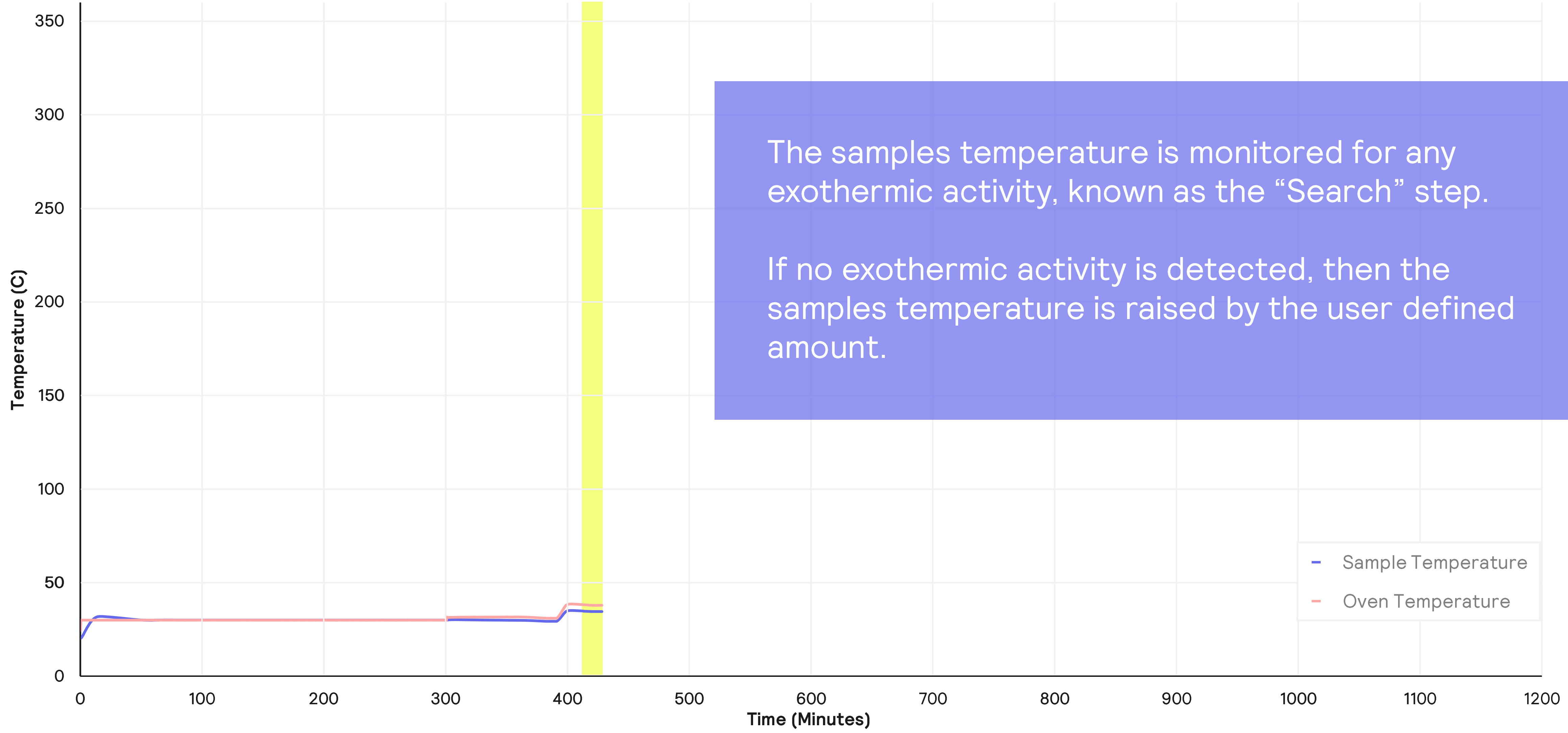
The "advance" of the guard heaters is also increased to help mitigate higher heat losses at higher temperatures.

The First "Wait" Step



The sample is held adiabatically and allowed to settle at the elevated temperature.

The First “Search” Step



The samples temperature is monitored for any exothermic activity, known as the “Search” step.

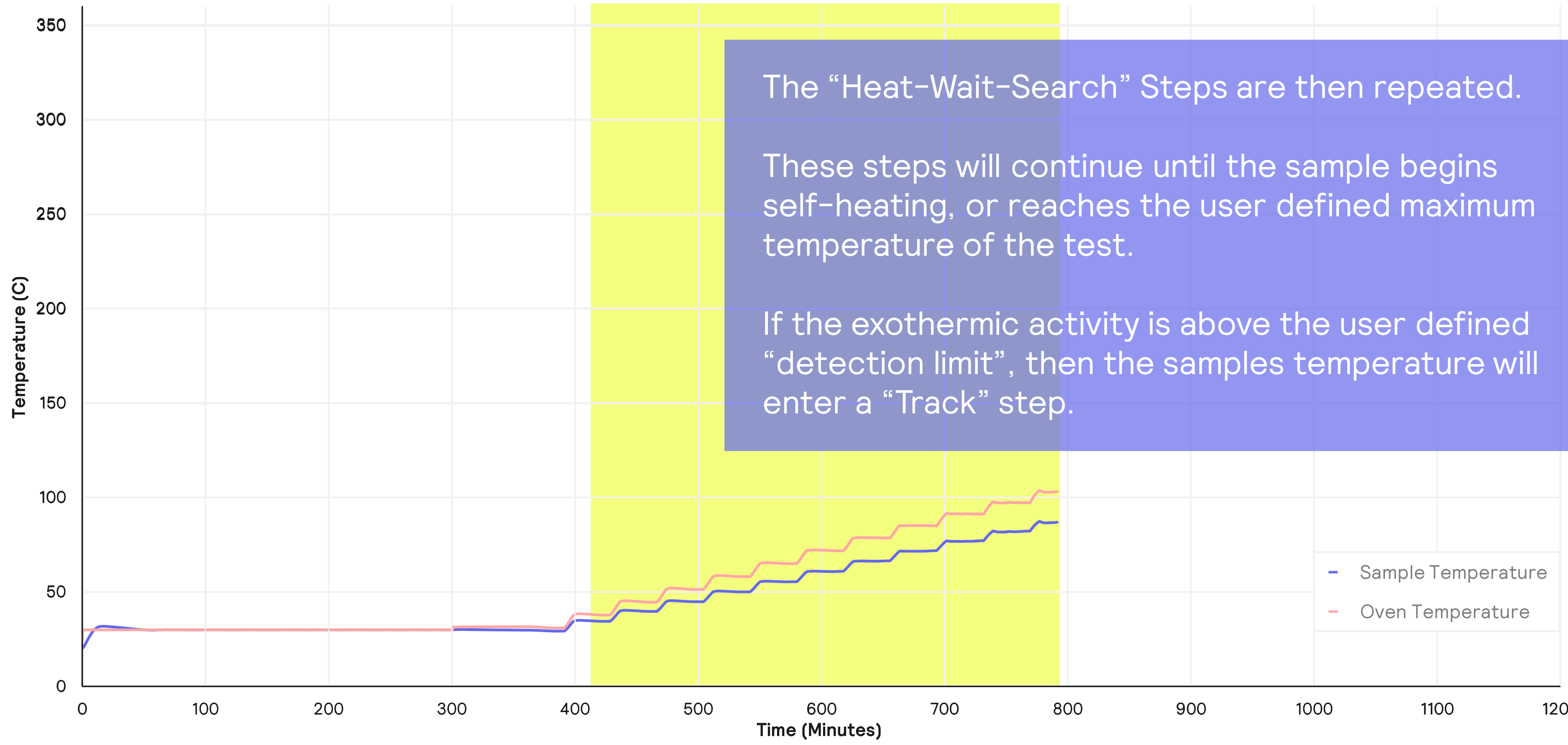
If no exothermic activity is detected, then the samples temperature is raised by the user defined amount.

The Heat-Wait-Search Staircase

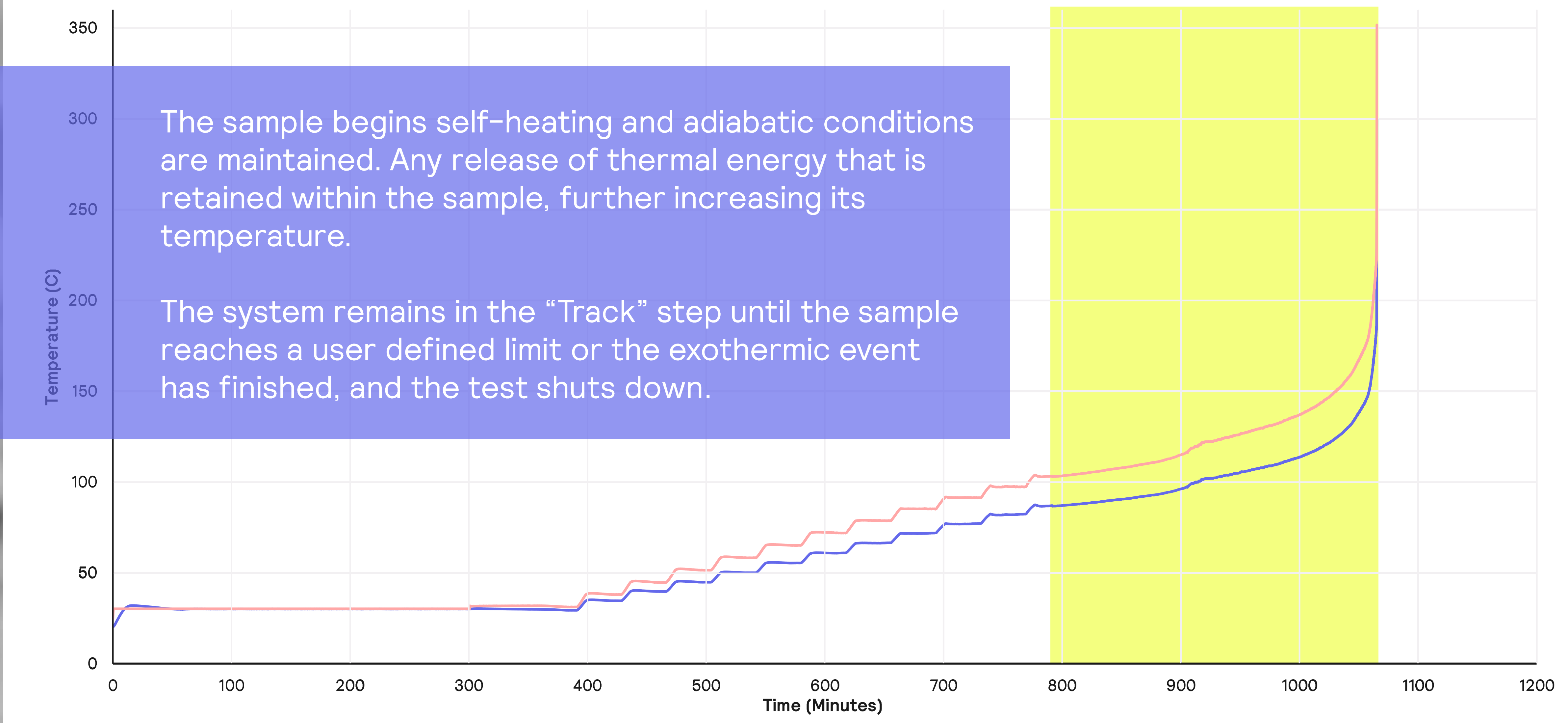
The "Heat-Wait-Search" Steps are then repeated.

These steps will continue until the sample begins self-heating, or reaches the user defined maximum temperature of the test.

If the exothermic activity is above the user defined "detection limit", then the samples temperature will enter a "Track" step.



Self-Heating, Triggering the “Track” Phase



The sample begins self-heating and adiabatic conditions are maintained. Any release of thermal energy that is retained within the sample, further increasing its temperature.

The system remains in the “Track” step until the sample reaches a user defined limit or the exothermic event has finished, and the test shuts down.

System Cool Down

The sample has now thermally decomposed and released energy as thermal energy.

The system then cools down, but still logs the temperatures and pressures of the sample.

Outcome of Safety Testing

Armed with the information from adiabatic and safety testing, we can:

- Identify safe operation temperatures
- Physically protect the battery
- Define safe charging conditions and management systems
- Design protective systems
- Design thermal management (cooling) systems

More information

https://helgroup.com/applications/solutions-in-battery-technology-testing/

Main Outcomes

Isothermal calorimetry works with batteries

- What are the basic principles of isothermal calorimetry?
- What information do we gain from isothermal calorimetry, and why do I care?
- What does this information mean and what can I do with it?

Adiabatic calorimetry with batteries

- What are the basic principles of adiabatic calorimetry with batteries?
- Why is it appropriate to gather this information for batteries?
- Why do I care about this information?

Thank you for listening

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